dc-SQUIDs for the readout of metallic magnetic calorimeters

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Superconducting quantum interference devices (SQUIDs) are the devices of choice to read out metallic magnetic calorimeters (MMCs). The latter are calorimetric low-temperature particle detectors providing a high energy resolution over a wide energy range combined with a very fast signal rise time smaller than 100 ns and a high quantum efficiency of up to 100 %. The detector output signal which is the change of magnetization of a paramagnetic temperature sensor is typically coupled to a SQUID via a superconducting flux transformer consisting of the pickup coil of the detector and the input coil of a current sensing SQUID. Because the energy resolution of MMCs is among other things influenced by the properties of the readout SQUID, it has not reached the fundamental limit so far. But as the signal size and the overall noise spectrum can be predicted with confidence, it is possible to design SQUIDs that are optimized for MMC readout. For the readout of MMCs with sub-eV energy resolution for example, a SQUID with a coupled energy sensitivity smaller than 15 h in the white noise region and a 1/f corner frequency fc < 200 Hz is required. This requirement is met by a two stage SQUID configuration where the actual detector is coupled to a first-stage SQUID whose output signal is amplified by an N-SQUID series array.

We have recently started the development of low-Tc current sensing dc-SQUIDs employing a Nb/Al-AlOx/Nb trilayer. In particular, we develop a second-order parallel gradiometer with an input inductance of Lin < 2 nH to which the actual detector is connected to and a 16-SQUID series array acting as a low-noise amplifier in a two-stage SQUID setup. We discuss our dc-SQUID designs as well as the properties of produced prototype SQUIDs. We investigate their noise performance with respect to the absolute value and the temperature dependence among others by using two-stage SQUID

configurations as well as a cross-spectrum measurement technique. We especially study the magnitude and frequency dependence of low-frequency excess flux noise. We found an intrinsic energy sensitivity of our first-stage SQUID as low as 2 h in the white noise regime and an excess flux noise contribution with an amplitude as low as 36 h. The coupled energy sensitivity of our 16-SQUID series arrays is below 6 h in the white noise regime and has a low-frequency excess noise amplitude of about 40 h. Using our currently best first-stage SQUID and 16-SQUID-series array, we built a two-stage SQUID setup which shows very low noise and which is competitive with the best available SQUID systems today and should be well suited for reading out our MMC detectors.